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IMPROVEMENTS IN SHIP REFIT STRATEGIES AND PROCEDURES: THE CASE OF THE ROYAL MALAYSIAN NAVY

by

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March, 1996

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Effective refit procedures and strategies is an important element in ensuring the high operational availability of ships. The Royal Malaysian Navy refit procedures and strategies which are based on the Royal Navy's procedures, are currently facing increasing drawbacks and the delay of ships in refit often goes beyond the acceptable period of thirty days. The factors which contributed to the delays are numerous and has cost the Malaysian Government considerably. With the reduction in the defense budget, accurate and economically sound procedures, strategies and decision-making are most essential.

To improve the procedures and strategies, this thesis evaluates the current Royal Malaysian Navy procedures and its drawbacks and subsequently outlines the U.S. Navy availability process for comparison. Finally, this thesis draws conclusions based on the comparison of the procedures and supporting tools. These findings offer immediate and medium-term actions and indicates further research that should be addressed in order to improve the current refit procedures and strategies for the Royal Malaysian Navy.

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IMPROVEMENTS IN SHIP REFIT STRATEGIES AND PROCEDURES: THE CASE OF THE ROYAL MALAYSIAN NAVY

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Effective refit procedures and strategies is an important element in ensuring the high operational availability of ships. The Royal Malaysian Navy refit procedures and strategies which are based on the Royal Navy's procedures, are currently facing increasing drawbacks and the delay of ships in refit often goes beyond the acceptable period of thirty days. The factors which contributed to the delays are numerous and has cost the Malaysian Government considerably. With the reduction in the defense budget, accurate and economically sound procedures, strategies and decision-making are most essential.

To improve the procedures and strategies, this thesis evaluates the current Royal Malaysian Navy procedures and its drawbacks and subsequently outlines the U.S. Navy availability process for comparison. Finally, this thesis draws conclusions based on the comparison of the procedures and supporting tools. These findings offer immediate and medium-term actions and indicates further research that should be addressed in order to improve the current refit procedures and strategies for the Royal Malaysian Navy.

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I. INTRODUCTION

A. BACKGROUND AND OVERVIEW

The Royal Malaysian Navy (RMN) was formed in the early nineteen forties with a few motor launches and steam propelled craft. Since then it has grown into a modern and sophisticated navy of missiles gun boats, frigates and corvettes. With the regional maritime situation in South-East Asia and with the intra-regional issues between neighboring countries, the role of the RMN has become increasingly important. Currently, the RMN is seriously considering acquiring submarines and the construction of a new generation of off-shore patrol vessels to increase its maritime capabilities to meet its responsibilities. In the long run, Malaysia requires an effective naval force to protect its waters and maintain jurisdiction and good order in the region.

As a third world navy, the RMN depends on foreign countries for the supply of ships and equipment. Since the early sixties, the RMN has purchased ships from various countries, such as Great Britain, Germany, Sweden, South Korea and United States. In most cases the ships were built in one country but equipment or systems were acquired from various countries. These systems were acquired because the systems fit the requirements of Malaysia, to modernize the ship or increase its capabilities. As a result, the RMN has a huge burden in keeping the Malaysian fleet operational and supplied with sufficient logistic support.

B. THE PROBLEM STATEMENT

The burden of maintaining the operational availability of the fleet at a high level is becoming increasingly difficult with the constant reduction of logistic and technical budget. Add to this difficulty is the increasing age of the fleet. This problem is not unique to the RMN and can be found in many other navies around the world. This study needed to be undertaken so that the reduction in defense budget would not affect the logistic service level and would allow the RMN to at least maintain its operational availability at sea.

When trying to provide the best possible logistic support to a ship, the logisticians of the RMN have depended on overseas suppliers for spares. They do this through the local agents and contractors. The supply of spares is acquired through an open tender exercise or in some cases through direct negotiation. The contract period varies between two to three years and the retender or the renewal of the contract period is done six months before the expiration date of the original contract. Each tender exercise undergoes very strict screening process and procedures, especially in the case of contracts with a value of more than one million dollars.

Understanding the life-cycle of a Navy ship, from the womb to the grave, is complex due to the fact that their operational availability is denied by the frequent need for maintenance and repairs, whether alongside the harbor, naval bases or dockyards. Logistic support must be recognized as the key element in the fleet operation. Any naval ship, no matter what the combat capabilities, constitutes a weapons systems of zero tactical effectiveness when it is in an "off-line" status in port, in a naval base or the dockyard for major repairs.

The logistic support of the RMN is made more difficult for the logistician and the technical personnel when ships are delivered from the exporting countries with little or no information on the ships development. The absence of historical data on the construction and development of a ship and its onboard system places the end-user and the ships support personnel at a tremendous disadvantage. The absence of data forces the user to be highly dependent on the manufacturers' recommended lists of spares and components. In my experience, the user is faced with huge discrepancies in support data and the spares variance. To summarize, a manufacturers' recommended list is commonly not totally dependable.

If the manufacturers' recommended lists are adhered to strictly, the depot may be carrying excess spares. This excess may run into millions of dollars of increased expenses. Some of the spares may not be used at all after a few refits. This places the spares into the category of dead stock, which can represent millions of dollars of expense after a few years. To date the RMN has dead stock for Mine Sweepers, Leander Class Frigate and other old ships that have accumulated into millions of dollars.

Thus an accurate acquisition procedure and a strategy for refitting ships is highly desirable. The cost and the complexity of the logistic support has risen with the technology of modern warships and has become of significant importance to the users to the operational fleet.

One of the major factors effecting the delay of ships undergoing refit in the yards is the timely availability of spare parts. The unavailability of these spare parts is the result of several factors. A primary reason is the inaccuracy of the MATPREP (Material Preparation). A large proportion of the spares that has been projected in the MATPREP as mandatory items was not utilized. An equal number of required spares was not covered in the MATPREP list but later demanded as additional spares. An analysis of refit reports showed gross inaccuracies in the MATPREP. The analysis was made by the head of the analysis cell in Fleet Material Command. The result is an increased concern for the effectiveness of the MATPREP.

C. DEVELOPMENT OF RESEARCH QUESTIONS

The ineffectiveness in the material preparation indicates the need for a study of the MATPREP system. This study examines the current MATPREP system, its weaknesses, and conducts a comparison with United States Navy system in order to identify solutions, and to suggest procedures to correct some of the problems and shortcomings of the MATPREP system. Although this study attempts to cover every aspect of MATPREP, there are some areas which, because of their obscurity, are not part of the study. These areas also lack of facts and figures on which to base recommendations or conclusions. The focus of the study addresses the more important factors of the system and its problems. Once the important factors are identified and solutions proposed other less obvious factors may be uncovered for further research.

The thesis focuses on the following questions:

- What are the weaknesses of the current procedures and strategies of the MATPREP?

- Can these procedures and strategies be improved by adapting U.S. Navy procedures?
- What areas are recommended for further research?

D. METHODOLOGY

Basic data for this thesis was obtained from the existing Fleet Material Commander Memorandum of RMN, the Head of Analysis on Refit of Fleet Material Headquarters of RMN and the United States Navy instructions, notices and policy manuals on ship's overhaul. The research was conducted in the following stages:

- An examination of each stage the current Fleet Material Commander Memorandum 1/92 dated 7 June 1992 on the refit procedures and strategies.
- An analysis of the weaknesses on the current procedures and strategies.
- An examination of the current overhaul procedures practiced by the United States Navy.
- Comparison and evaluation of the RMN and United States Navy procedures and development of strategies that would contribute to the improvement of the refit procedures.

The study will provide a strategic comprehension of the different refit procedures and strategies currently used in RMN and United States Navy and show how they provide for a work process and the ships material preparation for refit.

This study outlines the RMN refit procedure and strategy, and the United States Navy overhauling procedures and strategies process, from beginning to end. The roles of various cells or departments involved in the refit process are analyzed and their possible weaknesses are highlighted. In the final chapter, conclusions are presented and recommendations for potential areas of further research are made.

II. BACKGROUND ON THE CURRENT REFIT PROCEDURE IN THE ROYAL MALAYSIAN NAVY

A. RESPONSIBILITIES

The Fleet Material Commander (FMC) is responsible for maintaining the overall readiness of the naval fleet. This responsibility includes planning and programming the resources required for the maintenance and modernization of the operating forces of the Navy. The FMC and the Naval Headquarters approve all maintenance strategies for, ship maintenance plans, the fleet modernization program and depot level maintenance.

FMC is supported by the Repair Contract Division in the Naval Headquarters for awarding contract work to various successful shipyard. Central Naval Logistic Depot (CNLD) is responsible for procuring the required spares which are projected by Material Preparation Cell and the ship. These responsibilities are codified in the Fleet Material Commander Memorandum [Ref. 1]. Central Naval Logistic Depot is divided into three main areas of material control responsibilities as follows:

- Material Controller 1 - is responsible for the procurement and supply of main propulsion and generators items.
- Material Controller 2 - is responsible for the procurement and supply of radio and electronic items.
- Material Controller 3 - is responsible for the procurement of underwater and miscellaneous items.

The Fleet Operational Commander is responsible for the material condition of their assigned ships. This responsibility includes making the trade-offs among cost, scheduling and mission when assigning repairs and modernization availabilities, and the level of operational readiness of the fleet.

B. GENERAL SHIP MAINTENANCE AND REPAIR POLICY

The Fleet Material Commander (FMC) has set the following criteria as general policy for the maintenance of ships:

- The fleet will be maintained so that it is capable of meeting the threat and accomplishing the assigned mission.
- The fleet material readiness are to be maintained in accordance with the various maintenance level as prescribed.
- The planned maintenance schedule which is divided into two major categories, preventive or corrective are to be adhered to so as to maximize the reliability of the ship and minimize the maintenance workload.
- Modernization of the ships and equipment will be considered if required to ensure the future operational efficiency and requirement.
- The Department of Navy is to ensure the adequate funds are available for the purpose of ensuring material readiness of the fleet so that the fleet can meet established operational readiness level.

C. LEVELS OF MAINTENANCE

The FMC has categorized four levels of fleet maintenance schedule that must be carried out to ensure a high standard of the fleet material readiness through the ships life cycle as follows:

- Level 1 - Maintenance which has to be performed onboard by ship staff in accordance with the prescribed planned maintenance schedule.
- Level 2 - Maintenance which has to be performed while ship is undergoing self maintenance schedule with the assistance of base staff.
- Level 3 - Maintenance which has to be performed while ship is in port with the base staff.
- Level 4 - Maintenance level which must be performed in port by the base staff prior to refit period or carried out by a shipyard or contractor once it is included in the work scope as major defect or additional known defect.

D. SHIP MAINTENANCE STRATEGY

The RMN maintenance strategy is divided into three main categories as follows:

1. Maintenance Program

The maintenance program which is designed to keep the ship at a level of material readiness so as to maximize the operational availability of the fleet.

2. Fleet Modernization Program (FMP)

This FMP is designed to update the ship equipment and machinery as required to meet a current or anticipated enemy threat.

3. Service Life Extension Program (SLEP)

This program's purpose is to extend the service life of a ship's equipment beyond the original designed life. The SLEP is usually done in close coordination with manufacturer.

E. CONTRACTS

The spares contracts, both proposal and requirements, are initiated by Central Naval Logistic Depot. Maintenance contracts are a function of Fleet Materiel Commander Headquarters and are processed at least six months in advance. Maintenance and spares contracts are sent to the Contract Division in the Ministry of Defense for processing and tender. The Division assigns a contract administrator once the contract is awarded.

Most of the major systems and equipment contracts are signed with overseas suppliers and manufacturers. Local firms act as an agent or the representative of the overseas manufacture. The duration of the contract varies from one to three years with lead time provision between three to nine months. Usually, the values of such contracts ranges from one million to as much as thirty million dollars. For such high value contracts the navy cannot avoid elements of political pressures and influence from the interested parties. Administering the contracts may, at times, politically very sensitive and a frustrating experience.

Most of the contract clauses and provisions are not very firm and allow the contractors much leeway with provisions of minimal penalty. This puts the navy at a considerable disadvantage. The volume of the contracts and the lack of a management information systems result in the renewal of contracts being overlooked. This contributes to a delay in getting the refit spares. This is primarily the result of no on line ordering system and an absence of information technology for the use of navy.

F. ROYAL MALAYSIAN NAVY REFIT PROCEDURES

The RMN Refit Procedure is outlined through the Fleet Material Commander Memorandum No. 1/92 dated 7 January 1992. This memorandum encompasses the procedural instruction, coordinates meeting requirements, and establishes guidelines for the execution, implementation and feedback. The memorandum stated that historically the absence of spares for refit was the primary cause for delaying completion of a ship's refit. The problem has been identified and must be professionally addressed. [Ref. 1]

Early preparation of the Defect List and List of Spares is required to ensure that refit problems are minimized. As the Defect List and the List of Spares are interdependent, they must be thoroughly vetted and screened.

1. Procedure

The procedure for the preparation of the Defect List and MATPREP (Material Preparation/Requirement) that are required of the relevant departments are explained below.

a. Eight Months

Eight months before the refit start date, Fleet Refit Authority, Defect List Personnel (FRA- DLP) are required to send the Standard Defect List (SDL) and MATPREP to the ship for vetting and screening. All information and requirements must be in accordance with the ship's defects as recorded by the ship.

b. Seven Months

Seven months before the start date, a meeting is held with the ship's key personnel and FRA-(DLP) to officialize the Standard Defect List.

c. Six and One Half Months

Six and one half months before the start date, an official SDL will be issued by FRA and distributed to the relevant authority.

d. Six Months

Six months before the start date, an official MATPREP list is published in accordance with the scope of work of SDL and identified by FRA-(DLP). The MATPREP is divided into two categories, MANDATORY and NON-MANDATORY. The

MANDATORY spares will be marked with 'asterisks' (*) on the FMC 101 form. Four copies must be sent to the Central Naval Logistic Depots (CNLD) and two copies to Naval Maintenance Depot or in some cases to a large or capital ship.[1]

A large ship is required to send the Material Demand Form (BAT L 8) to CNLD for all mandatory items. FMC (MATPREP Section) would submit the MATPREP to CNLD on behalf of smaller ships.

The CNLD is required to vet and screen all MATPREP and earmark all the available spaces.

- In cases where the mandatory spares are not available, CNLD is required to initiate a procurement action.
- If the delivery date does not meet the required date, CNLD consult FMC for advice and direction.

Six months before the start date, FRA will send a letter of reminder to the ship requesting an Additional Known Defect List (AKDL) and MATPREP for AKDL. The AKDL should be based on the Urgent Defect (URDEF) and the ship operational status.

e. Five Months

Five and one half months before the start date, a meeting is held between the ships key personnel and FRA-(DLP) staff to verify the AKDL. Fleet Technical Authority (FTA) must conduct test on ship equipments. Larger ships with engineers assigned onboard conduct their own test.

Five months before the start date, FRA-(DLP) will issue an official AKDL to relevant authority.

f. Four Months

Four months before the start date, FRA-(DLP) will issue the MATPREP in accordance with AKDL identified work scope. The FMC 101 is issued with four copies going to CNLD and two copies to the Naval Maintenance Depot/or the capital ship. A

[1] In the RMN, the term capital or large ship refers to a frigate or larger vessel commanded by Commander or higher with a compliment of an engineering officer. A small ship is referred to small craft such as the gun /missile boat or smaller with a commanded officer of Lieutenant Commander or Libelow and without engineering officer assigned.

capital ship is required to forward the BAT L 8 for all mandatory spares to CNLD. For a smaller ship this function is performed by FMC (MATPREP Section).

g. *Two Months*

Two months before the start date, CNLD is required to return the completed FMC 101 to Fleet Refit Authority (FRA) and the Fleet Supply Authority (FSA). FSA is then required to forward one copy to the Naval Maintenance Depot and ship.

h. *One and One Half Months*

One and one half months before the start date, FRA-(DLP) will send a letter to the ship requesting the ship to prepare the 1st Supplementary Defect List (1st Supp). The 1st Supp list must be considered for approval based on the following criteria:

- The defect is beyond the ship staff/base staff scope.
- An approved A&A (Addition and Alteration).
- New defect after discovered after the preparation of the AKDL.

i. *Thirty to Fifteen Days*

Thirty to fifteen days before the start date, a meeting/discussion is held between key ship personnel, Principal Naval Overseers (PNO) and FRA- (DLP) to discuss the 1st Supp and pre-routine program. The pre-routine program includes the following:

- FRA- (DLP) and the ship will start by examining all equipment/systems that are directly known to be effective on the 1st Supp action.
- FTA is required to conduct Refit/DED/Ship Trial onboard ship to verify the defect.
- The ship is required to remove ammunition, fuel and stores prior to the refit. The fuel remaining should only be sufficient for the trip to the dockyard.
- A meeting concerning refit/shipping including the MATPREP should be held in FMC. The meeting is attended by the relevant authority or the representative from Department of Navy, FRA, CSO(M) Chief of Staff (Material), CNLD and key ship personnel. The meeting will discuss the work scope on SDL, AKDL, and A&A including the MATPREP list. The ship should contact CNLD to collect the MATPREP spares prior to entering the yard for refit.
- After the pre-refit/slipping meeting, FRA-(DLP) will issue an official 1st Supp List and MATPREP to relevant authority. A capital ship must forward the BAT

L 8 to CNLD for mandatory spares from the mandatory list, while this function for a small ship is performed by FMC (MATPREP Section).

- Prior to entering the yard, the ship is required to work closely with CNLD to collect all MATPREP parts available and to store these spares onboard.
- The "ship handing over" meeting at the shipyard is attended by representatives from FMC Headquarters, CNLD, the ship and PNO to discuss the defect list and other important matters.

When all the above requirements are met/completed, the start date of refit will commence.

2. Feedback

After the Refit Program is completed, Naval Maintenance Depot/Ship is required to provide feedback on all the work done during refit using the Refit Report Form.

Naval Maintenance Depot/Ship is required to provide the feedback and an analysis on the MATPREP. The depot must forward the MATPREP to FMC within two weeks of the ship's acceptance from the yard. The purpose of this report is:

- To analyze the usage of MATPREP spares during refit.
- To analyze the problems faced during refit or the probable problems that may be faced in a future refit.

3. Time Line

The time line for the RMN refit and procedure is shown in Figure 1.

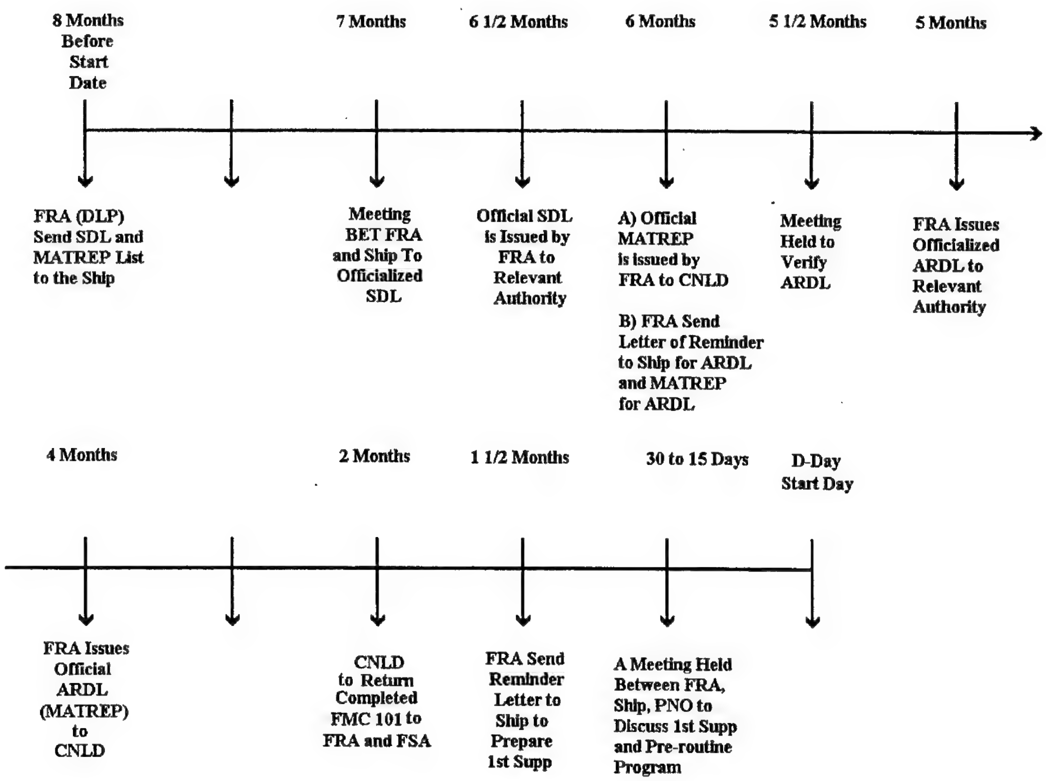

Figure 1. Royal Malaysian Navy Refit and Procedure

III. THE CURRENT MATPREP SITUATION

A. THE BASIS OF THE MATPREP

This chapter provides the current MATPREP situation in the RMN. The RMN MATPREP procedure and strategies are based on the ROYAL NAVY procedures and strategies, because most of Malaysia engineers and naval officers are British trained. The refit procedures have evolved over many years and have been modified through various memorandum. Initially, the problems were not critical because the RMN at the time was made up of a few small ships. Now, the problem is becoming critical, because the assets of the RMN run into billions of dollars, and the accurate prediction on the spares requirement has become economically and strategically important.

B. PREPARATION OF THE MATPREP

Material preparation, abbreviated as MATPREP, is the projection or forecasting of spare parts that will be required for the repair of ships undergoing refit/slipping routines. Currently, due to a lack of computers and the absence of computer networking, most of the work and the data for the MATPREP is manually collected and processed. The high rate of human errors in input to the systems is becoming a great concern. The actual cost implication of these errors is very difficult to determine. Whereas the computer world has Pentium processors and conductivity is changing the culture of many organizations with high speed networks and computers, we are still struggling with a limited number of 386 stand alone computers.

MATPREP is prepared based on the work scope which is identified in the various defect lists: Standard Defect List (SDL), Additional Known Defect List (AKDL) and the First Supplementary Defect List (1st Supp). The guidelines for the time of its preparation are covered in Fleet Material Command (FMC) General Memo 1/92. MATPREP for the SDL and the AKDL are prepared six and four months respectively prior to the Start Date (SD). MATPREP for the 1st Supp which should be prepared after the pre-refit/slipping

meeting (usually two weeks before SD) can be prepared. This is because at the time CNLD actions the MATPREP items for the 1st Supp; the 1st Supp has not received the actual spares requirements (based on the survey reports) from the maintenance depots. Therefore, the MATPREP that is being currently prepared by the Defect List Production Office (DLPO) is based solely on the work scope in the Main Defect List (MDL).

C. CLASSIFICATION OF SPARES

MATPREP is classified into two main categories:

- Mandatory items.
- Non-mandatory items.

1. Mandatory Items

The mandatory items are those items that must be changed based on the MDL work scope, plus some additional items which are added from time to time based on the feedback from the maintenance depots. These items are marked with an "*". CNLD takes immediate action on these items when the BAT L8 is forwarded to them by the FMC HQ (small ships) or by capital ships.

2. Non-mandatory Items

The non-mandatory items are made up of those spares that are subject to survey and inspection. Although these spares are projected in the MATPREP, CNLD does not take any action on these items unless they are actually required by the ship after the survey is completed by the yard. If these spares are not available at CNLD, orders are then placed. If the delivery time is projected to be very long, a non-availability (NA) certificate is issued to the yard for the purchase of the item, if the yard can obtain the item sooner than CNLD.

D. FEEDBACK FROM THE MAINTENANCE DEPOTS

On completion of the refit/slipping routines, the ship forwards the refit/slipping reports together with the feedback on the usage of spares in accordance with the FMC Memo 1/92. Generally these reports are delayed and they do not conform to the required format. An analysis of the reports shows that 75% of the reports received were delayed by more than

three months and only 10 percent of the reports were received within one month after the ships acceptance date.

E. ANALYSIS

In most cases a detailed analysis on the MATPREP is not carried out. This is mainly due to the lack of personnel in the DLPO; also very little emphasis is placed on the analysis of the refit reports received from the maintenance depots. The refit reports and the feedback on the MATPREP are related and are not analyzed for the same reasons.

IV. THE DRAWBACK ON THE PRESENT MATPREP SYSTEM

Limitations of the present MATPREP system creates delays for ships undergoing repair in the yards. The factors in the system that have contributed to the delays are as follows:

- Inaccurate MATPREP.
- Delay Start Date.
- Poor Control.
- Manpower.
- Work Growth in the Refit Process.
- Poor Maintenance by Operators.
- Spares Delay.
- Equipment/Test Facilities and Ships equipment is Antiquated.

A. INACCURATE MATPREP

1. Execution of MATPREP

In the current system the focus is primarily on the mandatory items. No action is taken by CNLD to procure non-mandatory items unless they are actually required after the survey reports have been forwarded. This makes the projection of the non-mandatory items in the MATPREP meaningless.

The mandatory list of items usually covers only a small proportion of the total spares required. The additional spares required (non-mandatory items), usually after the survey and inspection are complete, will have to be demanded from CNLD. If these items are unavailable, they are either ordered or NA is issued so that the shipyard can acquire the parts. This may incur severe lead times and is the start of the delay process.

Different engines, generators, gearboxes, etc. may have different requirements after the survey and inspection is carried out. It is difficult to project all the spares requirements accurately under the mandatory list and even if requirements are listed. The spares may not

be used and others not listed are required. These factors go only to the creation of more inaccuracies in the MATPREP. Because of these uncertainties, spares are listed as non-mandatory, and if they are not actioned, then delays are inevitable if these spares are not available at CNLD when required.

2. Conversion of Non-mandatory Items to Mandatory Items

Since CNLD only actions the mandatory items, the DLPO tends to push items subject to the survey, i.e. the non-mandatory items, (about 30%) onto the mandatory list [Ref. 1]. This generally increases the proportion of MATPREP items that are used but at the same time leads to "wastage" in large maintenance depots. The excess items are usually not returned to CNLD but instead are accumulated at the various maintenance depots. The accumulation of these items may be difficult to properly account and represent future problems. Therefore, the classification of the spares is vital and a solid basis for the process is essential rather than just relying on trial and error.

3. Computation of the Accuracy of MATPREP

The present system of computing the performance and accuracy of the MATPREP gives a misleading picture of the system operation. Presently, the computation is based on the proportion of the MATPREP items used over the total spares used. Additionally, the proportion of the mandatory items delivered by CNLD that are actually used is measured. Since the MATPREP items are based on the work scope in the MDL, if there is a lot added to the work scope in the 1st supp and the S339, requiring many spares, by definition the MATPREP will be inaccurate.

If a large number of spares that are required, but are actually covered in the non-mandatory list and CNLD only actions the mandatory items, these spares may not be accounted for in the MATPREP calculations.

For example, KD GEMPITA (Slipping 17 Oct 93 - 9 Apr 94); 164 spares were projected in the MATPREP for the 3000 hour routine on the starboard generator. The spares on the MATPREP were 105 classified as mandatory and 59 as non-mandatory. Feedback from the maintenance depot indicated that only 118 line items were actually used, 39 were on the mandatory list and delivered by CNLD prior refit/slipping. Twenty-seven were on the

mandatory list but a TT2 demand was made. Fifteen were on the non-mandatory list and a TT2 demand was made. Thirty-seven items were not projected at all. As far as the end-user is concerned, the MATPREP was accurate to 33 percent, but actual analysis shows that 69 percent of the total spares used were projected in the MATPREP.

Another good example is KD TODAK (Slipping 22 July 93 - 7 Aug 94); about 87 percent of the MATPREP items were issued by CNLD and out of these only 59 percent were used. There was a wastage of 28 percent. Additionally, the proportion of MATPREP items that were actually used constituted only about 9 percent of the total spares used in the refit. The poor showing of 9 percent cannot be blamed solely on an inaccurate MATPREP because the MDL constituted only 29 percent of the total cost of the slipping. There is a lot of work in the 1st supp and the S339 for which many spares are required but these spares are not accounted for in the MATPREP. However, it should be noted that in general, most of the works covered in the S339 are related to technical services such as cutting plates, excess work etc. On some occasions S339 also encompasses new defects which warrants spares, and these spares are not projected in the MATPREP.

Analysis of the delay of KD TODAK slipping shows that the late delivery of spares for the main engines, generator and gearbox attributed most of the delay in the completion of the ship. Further investigation revealed that the late delivery of these spares was because they were not projected in the MATPREP. This was due to the original work scope in the MAL, but as there were progressive delays to the SD and the running hours of the machinery accumulated, the work scope was completely altered during the pre-slipping meeting and spares for this alteration were not projected. This new work scope especially on main engines, generators and gearboxes was primarily a result of the added running hours. This itself was a result of the delay in the start of the routine by 8-9 months. The second MATPREP, to take into account of the new work scope, could not be actioned in time because it was planned at the original SD. So the root cause of the late delivery of spares was due to the progressive delays in the SD.

The above examples show that when a detailed analysis is carried out, other causes are more significant than the inaccuracy of the MATPREP. However, the inaccuracy of the MATPREP as one of the causes of the delay is not ruled out.

4. Feedback from the Maintenance Depot

Currently, the maintenance depots do not provide an actual usage of spare parts analysis. This is primarily due to the user unfriendly and unsuitable format required for effective analysis. For example, a FAC (G) consists of three engines, three gearboxes and three generators and each one of these may have a different maintenance routine, such as 3000 hours or 9000 hours routine, and each may have used different spares. The feedback sent by the maintenance depots on the usage of spares are not associated with the corresponding engines, generators or gearboxes. Instead, it is all combined in one list and it is difficult to identify which spares that have been used by the particular engine, generator or gearbox. Additionally, the spare parts are not listed under the equipment breakdown structure. For example, an engine has cylinder head, crank drive, turbocharger, gear train, etc for breakdown structure. It is also difficult to identify whether the parts were used to carry out the work scope in the MDL, 1st supp or the S339.

Since the MATPREP as prepared by the DLPO only covers the MDL work scope, it is necessary to identify the parts used according to which work scope. Then it can be determined whether the DLPO has achieved the objectives. This determination will omit the MATPREP as the cause of delay of spare parts. For example, if only 50 percent of the total spares used in the MATPREP were projected and the other 50 percent of the spaces were not listed in the MATPREP. For the work scope covered in the 1st supp and S339, as far as the DLPO is concerned, the objective of MATPREP is met. Then steps should be taken to reduce the work in the 1st supp and the S339.

There are also some doubt of the accuracy of the feedback from the maintenance depots.. There are cases where the mandatory items should be changed, but were reported not used. After checking, it was found that the items were actually changed but since the spares were used from the maintenance depot stock, or were given free of charge by the yard,

or were absorbed in the S339, the items accounting was not accurately reported. If details like this are not clarified, the blame could be placed on the MATPREP being inaccurate.

B. DELAY START DATE

The RMN is now required to perform additional responsibilities in its maritime duties. Old and insufficient assets often contribute to a planned start date being pushed forward to meet the operational requirement of the fleet. The duties and mission of the fleet varies from the domestic jurisdiction and safekeeping to the international commitment under United Nations. A delay in the start date would not only incur a burden on the ships and equipment but also contribute to the work growth.

C. POOR CONTROL

Due to the lack of detailed procedures and written guidance of manuals and sufficient data, it is difficult for managers of the system to set standards. In the absence of the established standard, it is difficult for the managers to establish a control mechanism.

Currently, there is very little emphasis on the analysis on the MATPREP due to the shortage of personnel in the DLPO. As a result, important data needed for a control mechanism for the system is not generated or available.

D. MANPOWER

Manpower is another factor that have been overlooked in past years. Many experienced personnel have left and joined the private sectors. This leaves the inexperienced who lack training and supervision. Personnel with the right attitude and skill are needed to ensure the job is accomplished in a right manner and meets standards.

E. WORK GROWTH

Work growth increases considerably from the initial stages of the MATPREP to the start date. This work growth hinders planning the completion date and demands additional man-hours and spares.

F. POOR MAINTENANCE BY OPERATORS

Even though in some cases the instruction and the manual are available, there is evidence suggesting the operators are not adhering to the standing instruction and maintenance schedules.

G. SPARE DELAYS

The major cause of the delays in the refit is due to the spares delay, they arrive at the right time, in the right quantity or even right items. The cause for these delays are considerable and an in-depth study is needed to address the process from the forecasting model to the contractual provision and clauses.

H. EQUIPMENT/TEST FACILITIES

Insufficient equipment and test facilities at the ships, depot and the yards has contributed to the delays in repair and delays of the validation of the operational status of systems and the equipment after undergoing repair. At times, many stages of the validation process were not done. Subsequently, the whole system and its equipment will have to be redismantled for repair and tested to accomplish the validation.

I. SHIP AND EQUIPMENT ANTIQUATED

Equipment and ships that were purchased beginning in the nineteen sixties and later are still in service. Supportability of these ships and equipment is very troubling and presents mind boggling difficulties for the planners, users and maintainers. In most cases the reverse engineering of the equipment must be done. Reverse engineering expertise must be sought locally or even overseas at a substantial cost.

J. SUMMARY

The above points which contributed to the delay of the ships must be addressed in a total approach. A close look at the U.S. Navy availability procedure in the next chapter would give the reader a considerable insight as to how a much bigger navy implements their refit process. The U.S. Navy Availability Procedure can be used as a guide in our effort to improve the RMN Refit Procedure. Even though this process should not be taken in total, it can be modified to some extent to meet the requirement of a small navy.

V. REFIT PROCEDURES AND STRATEGIES IN UNITED STATES NAVY

In United States Navy refit procedure and strategies are known as the Surface Ship Availability Planning Process. The work requests or job orders are in accordance with the CNSP Maintenance Manual as follows: [Ref. 3]

A. CLASSES

1. Class A

Class A is for the work that requires overhaul or repairs modifications, field charges, ORDALT's (Ordinance Alteration) or SHIPALT's (Ship Alteration) to sustain or improve the operation and performance characteristics of a system, subsystems or component being repaired or modified to meet the latest design and technical specifications. It is designed so that the end product would be like new in appearance, operation and performance.

2. Class B

Class B is for the work that requires overhaul or repairs to restore the operation and performance of a system, subsystem or component to original design and technical specifications. SHIPALT's or ORDALT's, field charges and modification are not done unless stated by the customers.

3. Class C

Class C is a repair work on the system, subsystem or component specified by work request or work required to correct particular deficiencies or malfunctions specified by the customer. The repair jobs must ensure the condition or malfunctions described are corrected.

4. Class D

Class D is for work that encompasses operating, inspection and reported work requests in which the customer cannot specifically identify the problem. This class requires diagnostic and various tests and inspections. The survey activities will report findings, recommendations and cost estimates for the customers authorization.

5. Class E

Class E is work that is required to incorporate all alterations and modifications specified for designated systems or components. The repair should demonstrate the successful check-out of the work accomplished and operability through all relevant interfaces.

B. USN PROCEDURES AND STRATEGIES

The overhaul procedures and strategies of the United States Navy can be classified into four basic categories as follows:

- Preliminary Preparation
- Alteration Planning
- Work Package Development
- Work Authorization

1. Planning Engineering Repair and Alteration (PERA)

PERA is to assist NAVSEA and Type Commander (TYCOM) for alteration and repair advance planning. At the beginning of the planning cycle, PERA consolidates all the required alteration and repair data and develops a planning schedule.

PERA assists the TYCOM by contributing to the planning of the ships availability with the review and schedule for a particular overall. The ship maintenance and configuration data are consolidated and reviewed in accordance with the class file by PERA. At the same time PERA also prepares and updates the class maintenance plans.

2. Overhaul Manager

The overhaul manager must be nominated by the ship. The manager should have overhaul experience and serve onboard through the entire overhaul. This task is preferably assigned to ship engineering officer.

3. Plan of Action and Milestones (POA&M)

POA&M is established by the ship as a schedule for all major evolution such as CSMP (Current Ship's Maintenance Project) update, design and repair ship check, work package determination tests and inspection, work definition conference and submission of

supplemental work. The plan is built around the ship deployment schedule. POA&M is reviewed and updated constantly for a period of 18 months to include charges and additional requirement.

C. ALTERATION PLANNING

1. The Fleet Modernization Program (FMP)

FMP dictates the alteration planning schedule including funding, material procurement and installation schedules. NAVSEA as CNO's agent controls Title K SHIPALT's and ORDALT's planning. TYCOM's control Title D and F SHIPALT scheduling and AER scheduling.

2. Alteration Planning Letter

The alteration planning letter is issued by NAVSEA listing the Title K SHIPALT'S and major ORDALT's plan. This letter is an advance notice to the relevant organizations and an authorization to adhere to the alteration design and material procurement, including the list of special program material (SPM).

On the other hand, Title D and F SHIPALT's and AER Program are issued by TYCOM and are authority for the design and material procurement.

Onboard design verification (ship checks) are conducted at the start of the planning cycle by NAVSEA to develop SHIPALT installation drawing.

3. Alteration Authorization Letter

NAVSEA usually issues an alteration authorization one year before the start date of the overhauling, or as it is known in the U.S. Navy the availability. Sometimes this letter include Title D and F SHIPALT's and AER's authorized by the TYCOM. List of material managed under special program and the responsible procurement agents are listed. The letter acts as an authority to cancel any alteration for which the drawings or materials will not be available for the overhaul.

It is the ship's responsibility to verify all listed alteration concerning the equipment onboard. If there is any discrepancies, NAVSEA is to be notified and keep TYCOM and

ISIC informed. Alteration drawing and material availability must be reviewed together in Work Definition Conference (WDC).

a. Work Package Development (WPD)

(1) Ship Configuration. Work package encompasses the authorized repairs and alteration, which accurately describe the ship configuration to support the planning and material procurement. The validation of the ship configuration is done periodically to verify and re-establish the ship configuration baseline. Configuration Data Manager (CCDM) together with the ship company is responsible to validate the ship configuration. Beside the ship configuration, SAIL (Ship Armament Installation LIST) is also periodically updated to validate installed ordinance equipment or ORDALT status. If the ship is carrying ammunition or ammunition handling equipment, they are to be included.

(2) The Ship Alteration and Repair Package (SARP). The work package is being defined in SARP and CSMP. However, SARP may be defined as follows:

- Baseline SARP. An assembly of programmed alteration and CSMP items.
- Preliminary SARP. It is an updated SARP to include CSMP purge and redeployment work definition test and inspections.
- Proposed SARP. It is SARP with cost estimation.
- Authorized SARP. It is the authorized SARP work.
- Completion SARP. It is an updated SARP to reflect work that is accomplished and its actual cost.

(3) Current Ship's Maintenance Project (CSMP). CSMP acts as a basic work package definition document in the phased maintenance planning and maintenance management systems. The work package development is updated by the ship force for its accuracy and a copy is given to PERA or TYCOM.

(4) Tests and Inspections. Once the CSMP has been streamlined and updated, a Work Package Development Plan (WPD), Pre-overhaul Test and Inspection (POT&I) Plan or Material Self Assessment Guide are issued.

It is the duty of POT&I to test and inspect the ship prior to overhaul. A complete test and inspection is conducted during the first phased maintenance to highlight

the material condition and follow up during the subsequent phase maintenance availability, Work Package Definition Plans and Material Assessment Guide are issued to include all the known defect and material condition.

PERA is responsible for preparing the WPD plan based on the input by the port engineer, ship force, ISIC and TYCOM representative and technical agents. Using this information the CSMP is updated.

b. Work Authorization

(1) Work Package Documentation. Automated Work Request (OPNAV Form 4790/2P) which is produced by the 3M system, documents the repair requirement and identifies the planned and authorized alteration [Ref. 4].

Once the work package has been vetted, the cost is calculated and estimate is made for the depot level repairs and alteration.

The work is reviewed for the intermediate maintenance activity (IMA) and the manpower budget is estimated based on the Work Definition Conference (WDC) or Work Package Definition (WPD).

(2) Work Definition Conference (WDC). This conference is usually chaired by TYCOM's representative and attended by PERA, the industrial activity representative, IMAV-C, technical agencies representative and the ship representatives.

At this conference, the SHIPALT drawings development and procurement status is reviewed. Any SHIPALT with unacceptable drawing or material availability is deleted. The repair package is reviewed based on the work priority, manpower availability, IMA/SF capability and capacity.

(3) Authorized Work Package. The authorized depot work package is then translated into bid specification for a private shipyard availability (overhaul) or job orders for a Naval Shipyard availability. Concurrently, the ship prepares a management plan.

Non-repair related planning such as onboard training and off-ship school plans are prepared by the ship to be included for the availability.

The planning action revolves around the ship maintenance planning program (EOC), phased maintenance, type of availability and the ship schedule.

The ship is responsible for availability planning including preparing the work package. PERA is funded by the TYCOM and NAVSEA to assist the ship to prepare the work package.

D. DUTIES OF SUPERVISOR OF SHIPBUILDING, CONVERSION AND REPAIR (SUPSHIP)

The main task of SUPSHIP is to coordinate all arrangements with private shipyard contractors. It is the duty of the SUPSHIP to award and administer shipbuilding, design conversion, repair and facility contracts at private shipyard.

The procurement activity is handled by the SUPSHIP which provides a contracting officer who is the only individual authorized to contract new or additional work or to release the contractor from any provisions of work specifications.

The overhaul responsibilities of SUPSHIP are divided into two main categories. First, the planning, SUPSHIP is responsible for all prior planning for ships in a class which includes the preparation of initial bid specification package and formalize the award of the contract. Second, overhaul, SUPSHIP manages the availability or the overhaul.

However, both tasks may be performed by SUPSHIP in the ships home port for availability within the geographical limitations. Throughout the planning phase, SUPSHIP is responsible for the advanced planning. After the specification and contract is awarded, the task of coordination and liaison with the ship, TYCOM and contractor is carried out by the SUPSHIP desk officer.

The SUPSHIP desk officer is responsible for all contractual aspects and advises the TYCOM on matters related to new work, work growth and progress. The SUPSHIP is also responsible for all legal and contract administration as the contracting officer.

The SUPSHIP performs the following functions in the work package development:

- Advance Planning
- Contract Award
- Act as a liaison between the ship, SUPSHIP and the contractor

E. DUTIES OF PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS (PERA)

The main objective of PERA is to provide intensive management for planning and to accomplish an efficient, orderly and timely ship depot availability. This objective is realized through the use of scarce management and engineering resources, the development of standard documentation, methods and procedures throughout all NAVSEA organizations that have maintenance and modernization responsibilities [Ref. 5].

PERA function is to assist SPMS and TYCOMS in developing and integrating the life cycle maintenance and modernization requirement of assigned ships. Assigned ship classes are provided direct support to SPMS in specific programs. PERA provides support for the TYCOMS by providing engineered support for the planning, screening, authorization and accomplishment of repair and modernization work packages based on work definition in the SARP.

PERA also performs other duties assigned or funded by its sponsors NAVSEA, SPMS or the TYCOM. Among these duties are as follows:

1. Advance Planning Agent

PERA will be designated in writing by either NAVSEA or the TYCOM to act as the Advance Planning Agent for a specific ship industrial availability. With this designation, PERA has the authority to act as agent for the NAVSEA SPM and the TYCOM in dealing with the Planning Yard, Planning SUPSHIP, design agents, procurement activities, Naval Supervising Activity, and other involved commands.

PERA integrates modernization and repair requirements into documents directly usable by the industrial activities and is responsible for maintaining effective and timely communications among the Planning Yards, Planning SUPSHIPS, TYCOMS, NAVSEA, Procurement agents, and Naval Supervising Activities.

2. Long Range Planning

PERA coordinates and implements the following tasks:

- Maintain liaison with NAVSEA and TYCOMs on PERA programs and with other activities in support of ship maintenance and modernization.

- Develops and implements a Quality Assurance (QA) program to ensure consistent, high quality PERA products and services.
- Administer assigned Ship Alteration (SHIPALT) programs.
- Manage NAVSEA tasks assigned to the Planning Yard or Planning SUPSHIP (as design agent) for SHIPALT Installation Drawings (SIDs) and other documents for authorized work.
- Prepares and maintains ships repair and alteration histories when tasked.
- For assigned SHIPALTs, identify material and ILS requirements for entry into the Fleet Modernization Program Management Information Systems (FMPMIS).
- Acts as the central manager for procurement, staging and delivery of long lead time material for assigned ship availabilities.
- Coordinate implementation of the Integrated Logistics Support Management Program (ILSMP).
- Manage special material programs.
- Develops CMPs and associated material usage forecasts to ensure ship systems and equipment are properly maintained. Updates the plans and forecasts to reflect current conditions.
- Prepares and manages the development of Integrated Test Plans.
- Assists the TYCOMs in implementing advance diagnostic techniques to improve repair work definitions.
- Assists in the configuration status accounting processes. PERA maintains and uses the ship's configuration data during routine operations and reports configuration data base errors to the designated configuration data manager (CDM).
- Maintains a databases of material required for equipment repairs. This database is used in forecasting repair material requirements and the costs for availability work packages.

3. Availability Planning

PERA performs the following availability planning tasks:

- Manages advanced planning requirements for assigned ship availabilities. Establish, coordinates, maintains, and ensures compliance with advance planning milestones. Provide periodic status of the planning progress.
- Develops a proposed comprehensive integrated repair and modernization work package in standard SARP format.

- Prepares Pre-Overhaul Test and Inspection (POT&I) and Work Package Definition (WPD) plans and material self-assessment documents. Conduct POT&I and WPDs to determine material condition if tasked.
- Prepares and distributes preliminary SARP for estimating by the industrial activity.
- Review the SHIPALT package and integrate it with the repair package. Examine compatibility with planned repairs and availability duration.
- Prepare and distribute proposed SARP for screening at the WDC.
- Task activities for planning Title D and F SHIPALTS, via the SPM Contracting Officers Technical Representative for the contractor planning yards.
- Prepare work package assessment for:
    - The adequacy of the work package to ensure ship's operational reliability and safety during the next operating cycle.
    - The ability of the industrial activity to implement the package within the funding and schedule constraints.
    - The degree of the compliance of screening actions with the current work assignment directives and reliability centered maintenance principles.
- Attend and participate in Work Package Definition Conferences. Develop, document, and retain all lessons learned and incorporate into the planning process.
- Prepare and distribute an authorized SARP that reflects TYCOM WDC decision and NAVSEA assigned SHIPALT's.
- Assess the effectiveness of the advance planning process.
- Provide cognizant activities with availability planning and material information such as:
    - Appropriate issues of the SARP
    - POT&I and WPD plans and reports
    - Technical specifications
    - Status and availability of justification and cost forms, SHIPALT records, and SHIPALT installation drawings
    - ILS information
    - Machinery Condition Reports
- Prepare and promulgate availability completion SARPs as requested.

Although PERA has the capacity to performing all of the above duties, they are often not tasked with many of them. Many of these tasks may be performed by the port engineer, as detailed in the following section.

F. DUTIES OF THE PORT ENGINEER IN WORK DEFINITION

TYCOM appoints a port engineer as its representative in overhaul planning, execution and evaluation matters and work in conjunction with ship's representative to ensure the availability is carried out professionally. The task is carried out with onboard observation, direct contract with ship's force, and through other TYCOM representative and maintenance support activities.

G. WORK DEFINITION PROCESS

In the United States Navy Availability Process, the work definition identifies repair work to be done and authorized SHIPALT as an integrated availability work package. In phased maintenance, it is called Work Package Definition which consists of the following elements: [Ref. 6]

1. Work Package Definition Plan (WPD Plan)

WPD Plan is a listing of tests and inspections performed during the Work Definition Inspection (WDI) to define a comprehensive repair package. PERA developed this document to be used by the port engineer in conducting the WDI. The listing is derived from the Class Maintenance Plan (CMP) or its accompanying Long Range Maintenance Schedule (LRMS), Naval Ships' Technical Manual (NSTM), equipment technical manuals and other sources. The listing includes tests and inspections for equipment and systems that have historical problems and other mandated time-directed tests and inspections.

The Plan consists of three parts namely a WPD Plan index, a recommended test and inspection agenda, and an individual equipment and system Repair Inspection Record (RIR) sheet. The WPD Plan index lists all of the significant maintenance items on the ship, and is commonly referred to as a Ship System Configuration Index (SSCI). The agenda shows the

interrelationship of various tests and execution of those tasks. RIR provide criteria for conducting inspections and tests.

2. Work Definition Inspection (WDI)

The WDI is a set of tests and inspections, reflected in the WDP Plan, used to determine the material condition of a ship's system and equipment and to pinpoint those in need of maintenance. In many respects, the WDI is similar to a POT&I. While both the POT&I and the WDI provide a basis for repair work decisions, POT&Is occur once per operating cycle, before the overhaul availability. Due to the long interval between overhauls, the POT&I is broad in scope, covering most of the ship's systems and equipment. WDI is presumably to identify all potential work items in order to reduce the risk of inter-availability failures.

For ships in phased maintenance, several program elements necessitate a modified work definition procedure. These elements include shorter and more frequent availabilities; a flexible cost-type contract vehicle; and an increased emphasis on condition assessment. WDIs are conducted about once every 15-18 months and yield a more concise and presumably usable preliminary SARP. The systems and equipment examined during a WDI are typically only those that have historically had problems or have been specified for time-directed assessment.

3. Work Package Definition Report (WPDR)

The WPD Report is immediately prepared upon completion of a WDI by PERA, acting as the TYCOM agent. PERA records the results in the WPD Report to provide the port engineer and TYCOM staff a useful list of potential availability repair work while awaiting the preliminary SARP and to serve as the basis for the preliminary SARP. The report consists of the WPD Plan, completed Ship's Maintenance Action Forms (4700.2Ks), and marked-up AWR-forms.

4. Preliminary SARP

The preliminary SARP is used by the port engineer to review initial repair decisions, to obtain preliminary estimates of availability costs from the planning supervisor, and to ascertain which items may be affected by known material procurement difficulties. In a

meeting with the planning supervisor and shipyard representatives, the port engineer reviews the preliminary SARP in detail to identify high priority items which require long lead-time material and exacting work specification development. With the concurrence of the planning, the port engineer usually sanctions the shipyard to begin work on the long lead time material procurement and writing of specification for those items by issuing an authorization letter.

5. Work Definition Conference

WDCs are held about six months in advance of availabilities for the purpose of authorizing work to be performed. The conference is chaired by the port engineer and attended by personnel from TYCOM, ship's force, planning supervisor, and PERA.

Often a pre-WDC is held to discuss preliminary repair decisions and to make preliminary assignments of the work among the depot, IMA, and ship's force. The purpose of the WDC is to make a final determination of the SHIPALT's and repairs that are to be accomplished by the industrial activity, intermediate maintenance activity, and ship's force. It refines the preliminary SARP into an authorized SARP.

In preparation for the WDC, the following actions are taken:

- Review the preliminary SARP in detail.
- Review the ship's CSMP.
- Review the shipboard vibration data logs.
- Interview leading petty officers and work center supervisors to document all new work.
- Inspect and verify the need and scope of SARP line items, ensuring that each SARP repair item is specific.
- Prioritize all depot level repair items, ensuring that the entire logistics package for the planned alterations is in place.
- Assess cost estimates for any new repair items and reassess estimates for existing items that appear to be too low or too high. Revise estimates for jobs for which the scope has been changed.
- Adhere to man day constraints imposed by OPNAV for each PMA work package. The authorized SARP must allow for subsequent emergent and work growth within this man day limit.

- Identify low priority items as candidates for cancellation or deferral.
- Achieve mutual agreement on the contents of the entire package.
- Provide ship's force with a list of low priority items and manday limitations and encourage ship's force to perform its own material condition assessments and to make sound trade-off decisions before submitting additional work items for accomplishment during the availability.
- Employ condition-based maintenance principles of Reliability-Centered Maintenance (RCM) decision logic in making or recommending repair authorizations to ensure discipline and consistency in the difficult process of prioritizing work.
- Authorized Ship Alteration and Repair Package.

The authorized SARP is the finalized work package prepared by PERA immediately following the WDC based upon decisions made at the conference. It becomes the foundation for formal work package cost estimates and detailed work specifications prepared by the planning supervisor or the PMA shipyard. Once the authorized version of the SARP has been received, the port engineer works closely with the planning supervisor and the shipyard in their preparation of work specifications and in identifying and procuring maintenance materials.

The port engineer is involved in the following ways:

- Participates in planning supervisor ship checks and clarifying questions that the specification writers have identified regarding the exact scope of each job listed in the authorized SARP.
- Informs the ship's PMA coordinator of any changes to the authorized SARP. The authorized SARP is published about six months prior to the availability. Changes that affect the work package often occur. Completed and new work items must be addressed. If a job in the SARP is accomplished prior to the availability, the port engineer must add any new work if unexpected equipment degradation or failure occurs. Low priority jobs may have to be deferred or reduced in scope to accommodate the new work within the man day limitations. Generally, more work is added to the PMA package following the WDC than is deleted. It is the responsibility of the port engineer to exercise discipline in controlling the size of the work package and simultaneously ensuring a logical overall prioritizing of work items.
- Modifies the scope of the authorized work package when necessary for material that cannot be obtained.

- Ensures the overall work package adheres to the OPNAV-imposed man day limits.
- Intermediate Maintenance Availability (IMAV) Work Package.

Upon receipt of the IMAV work package by the port engineer, about 45 to 120 days prior to the availability (A-45 to A-120), the port engineer takes the following actions:

- Reviews the IMAV work package in detail to ensure no items interfere with work screened to the shipyard for PMA accomplishment.
- Ensures that all items effecting the ability of the ship to light-off (start the engines) can be completed prior to the scheduled PMA light-off date. In cases where potential problems exist, the items are rescreened to the shipyard as new work to avoid PMA schedule delays.
- Ensures there is no redundancy or overlap between the PMA and IMAV work packages.

6. Pre-Arrival Conference

At about A-45 to A-30, the port engineer chairs a Pre-Arrival Conference attended by representatives of the ACO, phased maintenance contractor, Naval Supply Center, Squadron, Group, ship's force, and IMA. The meeting discusses a wide range of pre-availability preparation topics that directly impact the ship's schedule for the first weeks following completion of deployment. These include pier and berthing arrangements, fuel off-load, boat off-load, ammunition off-load, UNREP winch off-load, refrigerated cargo off-load, dry stores off-load, tank gas-freeing and cleaning, crane services, barge services, asbestos lagging insulation removal, early work start items, transportation requirements, and WDC following actions.

The port engineer oversees the interaction of all representatives to ensure that a reasonable schedule is established. The schedule should enable the timely accomplishment of all required items without placing unnecessary requirements or restrictions on the ship's force. If the ship's force is not represented, the port engineer must inform them of the schedule and any other pertinent issues that have arisen at the Pre-Arrival Conference.

Acting as principal points of contact between the ship and various other PMA participants, port engineers are the decision making focal points. Although the agents from NAVSEA, Planning Supervisor, ACO, TYCOM, PERA, the IMA, phased maintenance

shipyard, and equipment vendor technical representatives are involved in the success of an availability, the port engineer is intended to be in the best position to make sound, cost-effective repair and alteration work decisions. This provides continuity of management and an added dimension of engineering and logistics judgment through a first-hand working-level knowledge of the ship and its material condition. Personal experience and technical expertise in day-to-day ship repair practices are more extensive than available in a single individual under the other maintenance strategies. The port engineer concept enables the TYCOM to provide ships with valuable, hands-on services that are not otherwise available from type desk officers.

The steps of the United States Navy Availability Planning Process is shown below in Figure 2.

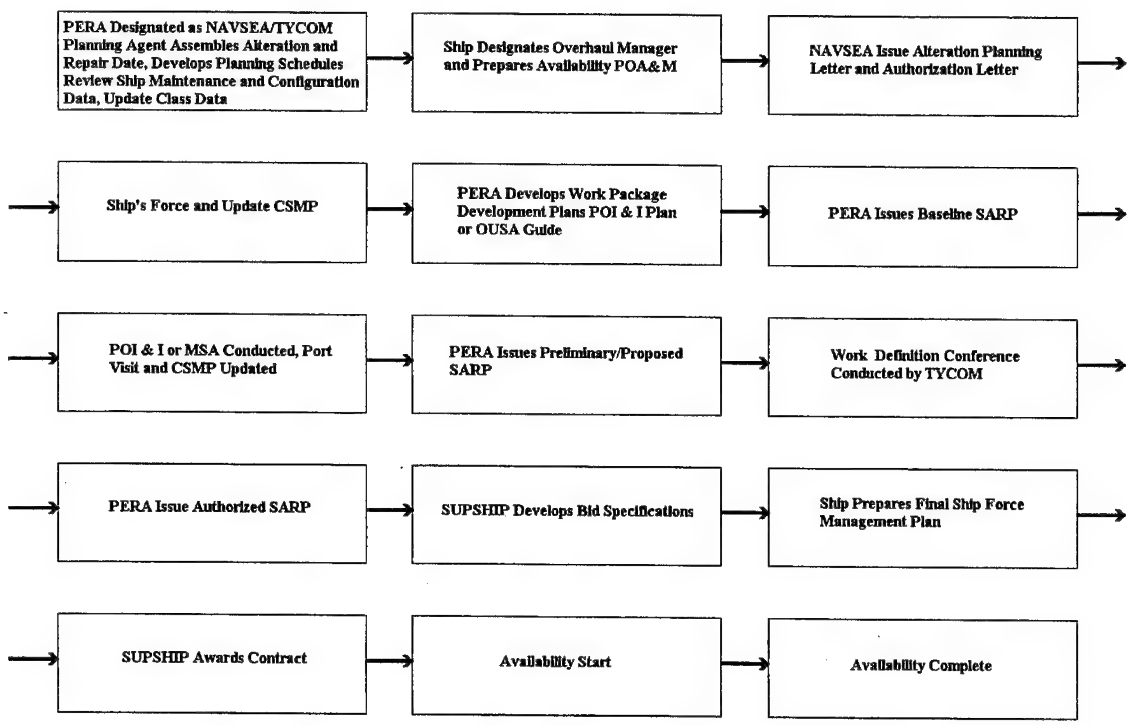

Figure 2. United States Navy Availability Planning Process

VI. EVALUATION OF RESEARCH FINDINGS AND RECOMMENDATIONS ON MATPREP PROCEDURES AND STRATEGIES

This chapter addresses the research question posed in Chapter I, and surveys the problems related to MATPREP. This chapter also includes observations of the procedures and strategies of the RMN in comparison with the U.S. Navy availability procedures and strategies.

A. RESEARCH FINDINGS

1. MATPREP Work Definition

As described in the Fleet Material Commander Memorandum No. 1/92 dated 7 June, 1992, the steps and procedures for outlining the work are in place. Based on the analysis using Figure 3, Development of Refit Strategy, and Figure 4, The Ishikawa Cause and Effect Diagram, it is evident that the problems are not due to the lack of directives and policies, but are the result of the management process.

Poor MATPREP management, lack of coordination and supporting tools within the MATPREP community lead to the poor MATPREP results.

In considering the factors which influence logistic support and subsequently the operational availability of ship/system or equipment, it is appropriate to first examine the factors or inputs which influence the system and effect process of ships maintenance and refit.

The inputs to the system and process can be categorized into two subsystems, namely the social subsystem and technical subsystem. In the social subsystem, the input variables are attitude, skill, knowledge and training (ASKT). In the technical subsystem, inputs are reference material such as manual and documentation, Management Information System such as computers/ADF, tools, database and maintenance planning including test equipment.

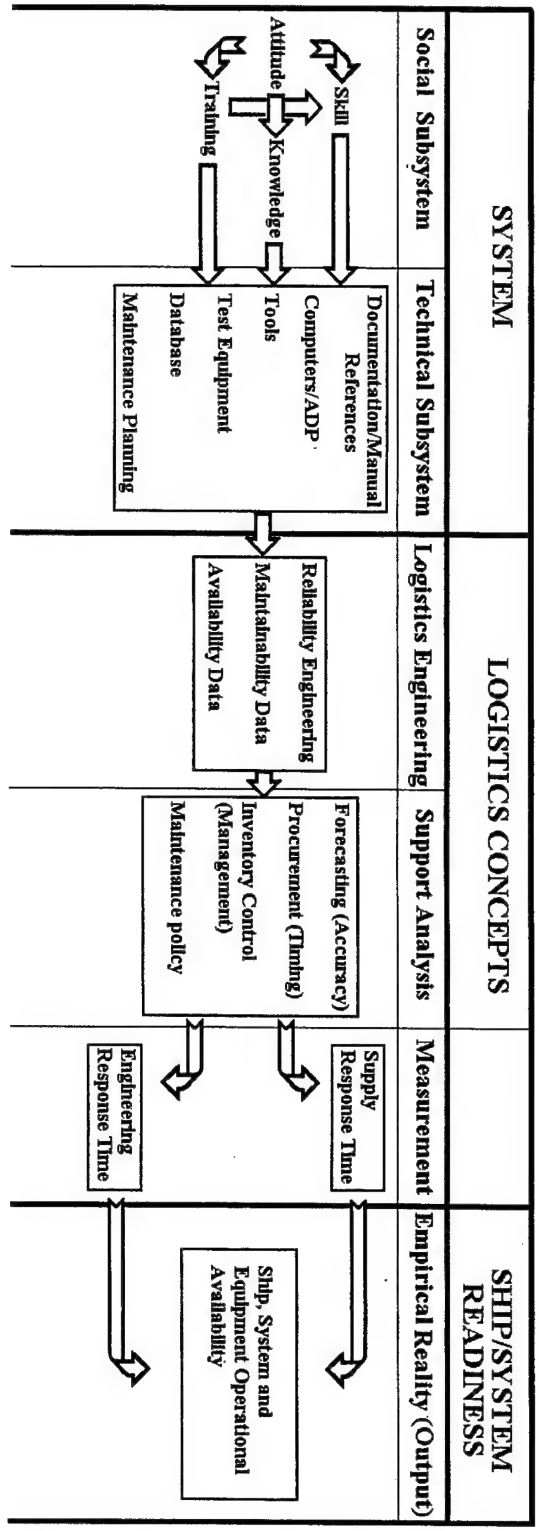

Figure 3. Development of Refit Strategy

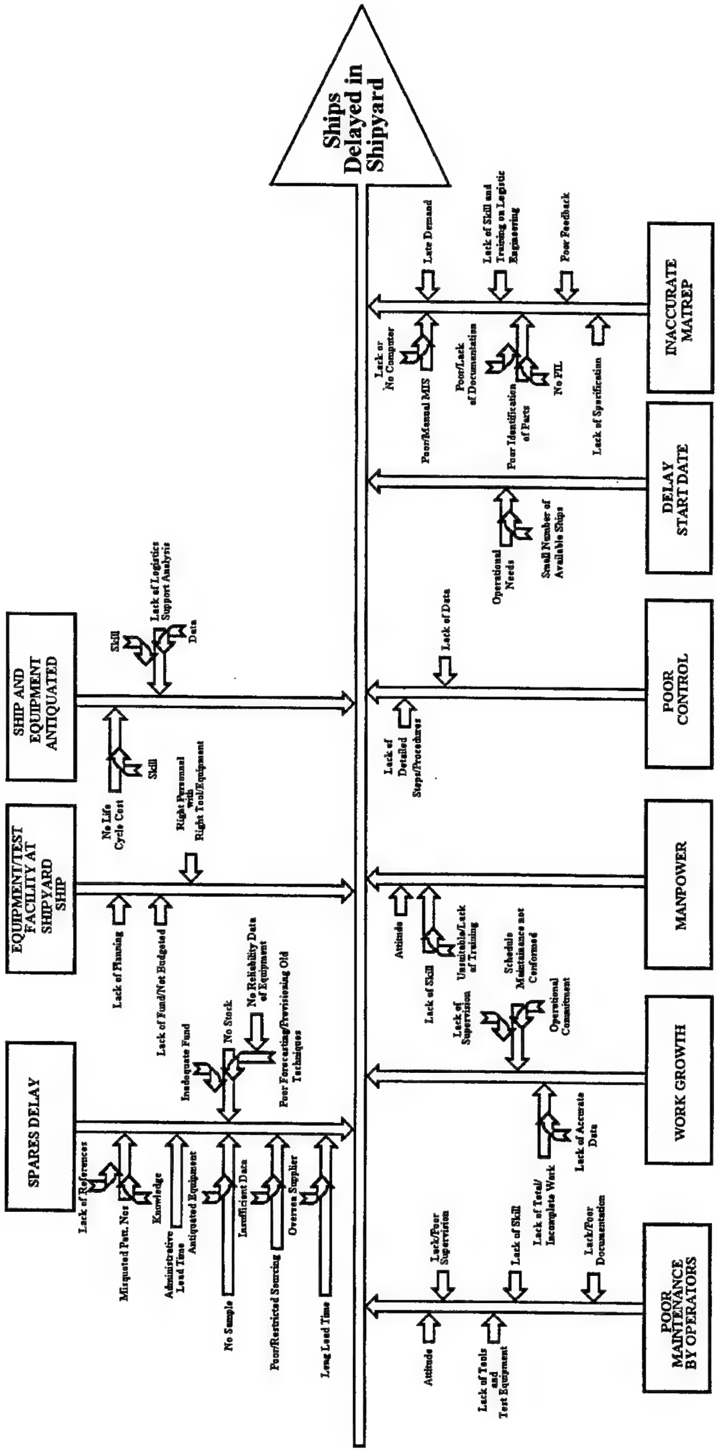

Figure 4. Ishikawa Cause and Effect Diagram

a. *Social Subsystem*

Attitude of MATPREP community is very important in ensuring that the weaknesses of the social subsystem are not contributed by the non-conformity to existing policy, instrument and directives. It is important that the general manager have the following skills [Ref. 6].

- Keep open many pipelines of information.
- Concentrate on a limited number of significant issues.
- Identify the corridors of comparative indifference.
- Give the organization a sense of direction with open ended objectives.
- Spot opportunities and relationships in the stream of operating problems and decisions.

Another important social input is training. Training has been proven to develop skill and knowledge and even influence attitude. Subsequently, skill and knowledge contribute to the efficiency and effectiveness of the system. In the author's experience, the MATPREP community have no dedicated training for the job. The job is done as an appointment and the assigned personnel must use their experience and initiative or even rely on trial and error in a vacuum of hard data to accomplish even poor results. Many of the personnel are not experienced with information technology and lack of basic computer skills.

A detailed task analysis which compares the quantity and the skill level of the personnel required with the number of personnel and skills within the organization would be most effective in determining the requirement for training of personnel. Training requirements should include both the training of personnel initially assigned to the job and their replacement.

From the analysis, the author has concluded that the MATPREP community is making decisions on ambiguous information such as in MDL SDL and AKDL. These ambiguous information sources must be sent back to their sources for clarification which contributed to the refits delay. This information ranges from inaccurate pattern number of the spares, wrong nomenclature for the equipment,

incomplete description of work to be done, inaccurate quantity of spares requested and finally to unclear specifications.

This has caused the social subsystem to spend considerable time and resources in reproducing the data to compensate for poor initial quality of information. The delay due to reprocessing of incoming information can be translated as the price of non-conformance.

The system can also benefit from the feedback of previous experience captured and documented as historical data. The benefit would contribute not only to technical matters but also to management processes. For example, the recurring parts changes, capability and peculiarities of a specific shipyard, time taken to repair equipment and supply lead time are some of the information which may be fed back into the system. The high turnover of personnel involved in this process is also an important factor that has a negative impact on the system. Coupled with the lack of automated data storage which does not allow for iterative analysis and restricts the 'learning curve' to trial and error, has caused the same mistakes to be repeated over time an again [Ref. 7].

The typical complaint among the MATPREP community or personnel is that they are required to repeat work to compensate for someone else's errors or inadequate work earlier in the process. The MATPREP system to be as efficient and expeditious as possible must be built on a positive basis with a Total Quality Management approach.

b. Technical Subsystem

The current level of MATPREP accuracy in the RMN has been reported to be between 40 and 50 percent. The MATPREP is prepared based on the information presented in the MDL. MDL however is prepared based on a series of references to manufactures manuals, tests, inspections and past experience.

At this juncture, the technical subsystem inputs such as documentation/manuals, ADP, tools, test equipment, database and Planned Maintenance Schedule have a major influence on the level of accuracy of the MATPREP. An accurate input to the MATPREP is critical to the refit program and requires an in-depth study.

The absence of ADP in the MATPREP system has deprived the organization of the ability to generating much needed data for the "accurate" planning and execution of MATPREP. The logistics engineering data on reliability, maintainability and availability is also lacking. Without this data conducting an accurate logistic support analysis is impossible [Ref. 7]. Forecasting of spare requirement, procurement timing, inventory control, preparation of MDL and formulation of maintenance policy is adversely affected as a result of the lack of an ADP system.

In the author's experience the references such as manuals, handbooks, training publication, maintenance publication, spare lists, equipment lists, drawing and diagrams, are lacking especially for the old ships and equipment produced by vendors to the original contractor. This has contributed to the difficulty of identifying parts and also hinders maintenance decisions. Similar problems are found with tools and test equipment. This is especially true at 3rd level maintenance (depot level) where diagnostic function are also affected.

c. Summary

The imbalance between the equipment introduced in the RMN and its logistic engineering support is very striking. The development of the social and technical subsystem have failed to match the rapid acquisition, technological and operational pace of the equipment that is currently used in the RMN. This is evident in that provision for supporting inputs in MATPREP is lagging the acquisition of equipment, resulting in a cycle where the operational availability of this equipment is ever diminishing.

2. Supply Response Time

The start date is about six months from MATPREP. In the author's experience the supply response time is insufficient when some spares are required. Furthermore, some spares have long lead times, more than six months as is stipulated in the contract for their purchase. The problem is more acute if the spares are demanded while the ship are under refit and a delay of more than 60 days are unacceptable. Some jobs or repairs are further delayed due to the absence of a small number of critical items, thus making the repair impossible to complete on the required date. The existing regulations and policies on the

procurement of spares for ship refitting programs are inadequate and the regulations need to be addressed for long lead time items and urgently needed spares that hinder the completion of the repair.

The spares which are frequently found to be the main cause of delays in refits are those normally associated with the main engines, gearboxes, generators and the ACU system. Furthermore, these spares are imported from foreign countries.

The problem can be solved by finding alternative methods of repair and replacement by using 'floats' and repair cycle for these items. A study on repair of these items by replacement and floats should be carried out to determine the cost effectiveness of the system.

3. Ship Days 'Lost' At The Yard

Delays at the yard incurred additional unnecessary cost to the RMN. The RMN should work with the yard to reduce the delay with the goal of the ship being completed on time.

Based on the data collected and shown in Table 1, the frequency tabulation of 166 samples of ships that has undergone refit at various yards from 1990-1995. In Malaysia a delay of 30 days is acceptable. From the data, 80 percent of the ships that had undergone refit experienced a delay of more than 30 days due to various reasons, mainly spares.

The mean delay time at the yards is about 59 days. The high standard deviation of 116 indicates the delay varies quite widely. The data also indicated that the distribution is positively skewed with an interquartile range of 54 days. This means that half of the delay days are encompassed between 5 to 113 days (59 days + 54 days = 113 days, 59 days - 54 days = 5 days)

4. Quality of MDL

The quality of MDL is base on planned maintenance that varies from ship to ship of the same class. While some ships do an excellent job in keeping the maintenance, some do not. This variability may relate to the inaccuracy of the MDL and 'work growth' during refit.

Class	Lower Limit	Upper Limit	Mid Point	Freq.	Rel Freq.	Cum Freq.	Cum Rel Freq
At or Below		0		33	0.2245	33	0.22
1	0	31.82	15.91	54	0.3674	87	0.59
2	31.82	63.64	47.73	24	0.1633	111	0.76
3	63.64	95.45	79.55	15	0.1020	126	0.86
4	95.45	127.27	111.36	4	0.0272	130	0.88
5	127.27	159.09	143.18	5	0.0340	135	0.42
6	159.09	190.91	175	1	0.0068	136	0.93
7	190.91	222.73	206.82	2	0.0136	138	0.94
8	222.73	254.55	238.64	1	0.0068	139	0.95
9	254.55	286.36	270.45	0	0.0000	139	0.95
10	286.36	318.18	302.27	0	0.0000	139	0.95
11	318.18	350.00	334.09	0	0.0000	139	0.95
12	350.00	381.82	365.91	2	0.0136	141	0.96
13	381.82	413.64	397.73	0	0.0000	141	0.96

Mean = 59.73
SD = 116.06
Median = 21.00

Table 1. Frequency Distribution - Ship Days Lost at Shipyard 1990-1995 [Ref. 2]

MDL varied along three quality dimension, validity, accuracy and completeness which contribute to 'work growth'. In some cases, work which should rightfully be done at the ship level or depot level is brought forward into refit. This resulted in 'work growth' when ship undergoes refit.

Secondly, the accuracy of the part numbers or description of the equipment to be repaired. This is a critical piece of information, especially in the case of the equipment that has been superseded. If the part numbers or description are in error, incorrect spares will be ordered and the resulted repair will not be done or completed.

Thirdly, MDL may involve the incomplete information. Incomplete information usually hinders the procurement process and repair to be performed. Usually, the most accurate information is determined after the ship arrives at the yard, and after the equipment

or the system has been opened and examined. At this stage, any newly discovered information only contributes to the delay when spares are not available and must be ordered overseas. The absence of an ADP system for tracking maintenance and configuration control have caused this problem.

5. Logistic Linkages

The author has observed that there must be a linkage between the social and technical subsystem through integration of the systems. Social inputs lack of technical inputs will eventually reduce the effectiveness and efficiency of the entire system. The imbalance between both inputs clearly contributes to integration or joint optimization of the whole system. The availability of the equipment is directly related to the reliability, maintainability and the effectiveness of the support at various levels [Ref. 7].

6. Support Analysis

It is not a very profound realization that with the problems mentioned, the maintainers are unable to perform effectively the function of logistic support analysis. This is due to the various shortcomings such as a lack of ADP support, inadequate forecasting methods, and contract provision and policy [Ref. 8]. Owing to the increasing age of the ships/systems/equipment in the RMN and with many prototype ships in the fleet, the requirement for an effective and efficient Integrated Logistic Support within the RMN is critically needed.

B. A COMPARISON OF ROYAL MALAYSIAN NAVY REFIT PROCEDURES WITH U.S. NAVY AVAILABILITY PROCEDURES

The words ‘Refit’ in the RMN and ‘Availability’ in the U.S. Navy are used to represent and ‘overhaul and repair’.

The U.S. Navy has a much earlier start date for refit preparation. Some time as early as one year as compared to the RMN which starts eight months before the start date.

The U.S. Navy has a very detailed outline of responsibilities, mechanics and procedure, guide, references and supporting tools such as ADP/computers and 3-M manual

in place. In these areas, the RMN is glaringly inadequate and requires a concerted effort for improvement.

In case of long lead time items, which are given emphasis in the U.S. Navy Availability Process and where help is provided for their procurement, a similar process should be considered in the RMN for preparation and signing the spares contracts.

The U.S. Navy has a pool of experience and specialist personnel in planning and executing the availability process. The RMN should consider acquiring these resources through FMS where the transfer of technology and know-how can be materialized. This would improve the refit procedures and process in the RMN. The improvement in the RMN Refit Procedures and Process would certainly lead to huge time and cost saving.

C. STRATEGIES AND RECOMMENDATIONS

The strategies and recommendations are largely based on the theoretical framework of this thesis. This framework can be divided into immediate and mid-term action. They may be adopted for implementation singularly or in various contribution which may be convenient.

1. Immediate Action

- The level of spares in the RMN for refit should be increased through consolidation and procurement basing on a revised forecasting model. On-line ordering of spares using computer networking would be desired to reduce the administrative delay.
- The spares for refit on the first ship should be used as a datum for the refit of the next ship of that class.
- A revised forecasting model should be implemented based on a separate study jointly with consultancy of experts in the field.
- A study of a float system for repair by replacement should be conducted. A float system would speed up the refit process and would be a cost-saving to the government and help to reduce the war reserve requirement.
- Automation in the area of MIS and date management is urgently needed. The RMN should look into the area of computer aided engineering and computer aided logistic and integration and networking application. The ILS area should be given

emphasis and a consultancy work in this area must be done by experienced and established Navy personnel.

- It is important to instill an awareness of Total Quality Management principles in the MATPREP process so that the cost of non-conformance in terms of time, material and effort could be reduced.
- Turnkey basis for refitting of ship should be developed. Each class should be given a selected shipyard through on direct negotiation basis. The shipyard should be made responsible for the supply of all critical items that cannot be supplied by the Navy or CNLD. This would reduce spares delay for the refit and it would indirectly contribute to the development of the shipbuilding industry. This industry is important to development of National Defense Industry.
- It is strongly recommended that a consultancy package with U.S. Navy be acquired through Foreign Military Sales in order to obtain expertise and for the development of a possible paradigm shift from the traditional Royal Navy concepts to U.S. Navy method of management.
- More officers and men of the Royal Malaysia Navy should be trained in U.S. Navy Management Schools. The Navy could recruit U.S. professors with military backgrounds to teach in our Military University and Colleges. Exchange programs could be arranged for faculty staff, officers and men so as to expose Navy personnel to U.S. management methods.

2. Medium Term Action

Further research is needed to ensure that logistics support is compatible in all aspects. Integration of the elements of logistic support would optimize maintenance and operational systems. Trade-off studies should be done to realize the benefit of integration of the logistic and maintenance systems.

The complete interaction of the logistic support programs with all other elements of organization is very important [Ref. 9]. These should include the following:

a. Program Planning and Control

Development of Early Logistic Support Analysis (LSA) Strategy - by defining Program objective.

- Logistic Support Analysis Plan (LSAP)
- Program Reviews/Design Review

b. Mission and Support System Definition

- Using operational requirement and maintenance concepts.
- Mission hardware, Software and Support System Standardization (Quantitative and Qualitative System - Level Design Criteria)
- Comparative Analysis (An examination of Alternative Approaches considering Readiness Objectives, Reliability and Maintainability Factors, Life Cycle Cost, etc.)
- Technological Opportunities
- Supportability and Apportability Related Design Factors (Design Criteria Resulting From Comparative Analysis)

c. Preparation and Evaluation of Alternatives

- Functional Requirements Identification (Functions, Operating and Maintenance Functions, Allocations, FMECA (Failure Mode, Effects and Critical Analysis), RCM (Reliability-Centered Maintenance Program) etc.
- Support System Alternatives (Identification of Alternative Support Concept)
- Evaluation of Alternative and Trade-off Analysis (Support System Trade Offs, Level of Repair Analysis, Evaluation of Alternative Diagnostic Concept, etc).

d. Determination of Logistic Support Resources Requirements

- Task Analysis (Detailed Operator and Maintenance Tasks, Major Procedures, Identification of logistic Support Resources Requirement)
- Early Fielding Analysis (Impact of Introducing New System on Existing Capability)
- Post-Production Support Plan.

e. Supportability Assessment

- Supportability Tests, Evaluation and Verification (Test and Evaluation, Strategy and Plan, Test, Data Collection and Analysis, Corrective Action and Reporting).

D. CONCLUSIONS

The answer to the research questions are as provided below.

1. The First Research Question

What are the weaknesses of the current procedures and strategies of the MATPREP? The weaknesses of the current procedures and strategies that are shown in Figure 4 - The Ishikawa cause and effect diagram. They are as follows :

- Inaccurate MATPREP - which contributes to: poor MIS, lack of documentation, poor identification of facts, lack of specification, late submission of demand, lack of skill and training on logistic engineering and poor feedback mechanism.
- Delay Start Date - as result of operational requirements which does not commensurate for the small number of available ships.
- Poor Control - Due to the lack of detailed steps, procedures and data.
- Manpower - due to the unsuitable or an absence of training and in some cases to the attitude of the personnel.
- Work Growth - due to the lack of accurate data, operational commitment, supervision and incomplete repair work.
- Poor Maintenance by Operators - due to the attitude of personnel, lack of tools and test equipment, lack of supervision, skill and poor documentation.
- Spare Delay - due to inaccurate pattern numbers, administrative lead time, unavailability of samples, poor and restricted sourcing, long lead time, and little stock availability.
- Unavailability Equipment/Test Facility at the Shipyard - due to lack of planning, funding, and right personnel with right tools and equipment.
- Ship and Equipment Antiquated - a result of purchasing of second hand ships, prototype ships and equipment, without life cycle cost data and a lack of Logistics Support Analysis.

2. The Second Research Question

Can the procedures and strategies be improved by comparing to the U.S. Navy procedures? The answer is 'Yes', by focusing on the following:

- Start Date - implement a much earlier start date, one year as practiced by the U.S. Navy.
- Procedures - detailed procedures and supporting tools such as being used in U.S. Navy now can be adopted by the RMN.
- Long Lead Time - spares that has a long lead time should be given emphasis in contractual agreement and procurement process.

- Control - the U.S. Navy has detailed availability responsibilities and control mechanism with a vast array of experienced personnel which the RMN can learn from through transfer of technology and know-how.
- Capturing Information - U.S. Navy is extensively using computer networking to capture information and data. They rely on this input to their refit systems. This system should be considered by the RMN for adoption.

3. The Third Research Question

What areas are recommended for further research? The areas that are recommended for further research are as follows:

- The effect of purchasing prototype ships for the service and its implication to supportability of these vessels.
- The validity of the current forecasting model used in the RMN.
- The life cycle of cost of various major equipment currently in service.
- The cost of float and repair by replacement that could be adopted by the RMN to reduce the delay of refit in the RMN.
- The break-even cost analysis on old equipment currently used in the RMN. A decision must be made either to continue or discontinue old equipment or replacing it with new equipment to reduce the economic and maintenance burden to the RMN.

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